AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

# A-level PHYSICS

Paper 2

Wednesday 21 June 2017 Morning Time allowed: 2 hours

**Materials**

For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae booklet.

**Instructions**
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

**Information**
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 85.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

| For Examiner's Use | |
|---|---|
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8–32 | |
| **TOTAL** | |

## Section A

Answer **all** questions in this section.

**0 1 . 1** A number of assumptions are made when explaining the behaviour of a gas using the molecular kinetic theory model.

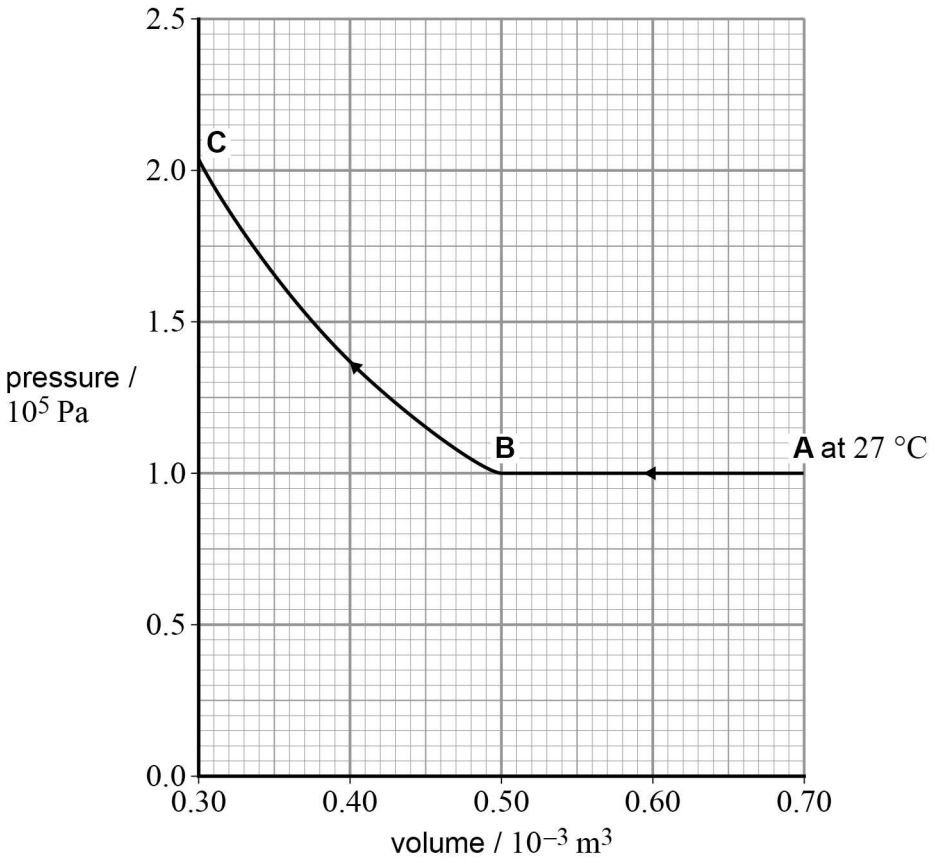
State **one** assumption about the size of molecules.

**[1 mark]**

**Figure 1** shows how the pressure changes with volume for a fixed mass of an ideal gas.

At **A** the temperature of the gas is 27 °C. The gas then undergoes two changes, one from **A** to **B** and then one from **B** to **C**.

**Figure 1**



**0 1 . 2** Calculate the number of gas molecules trapped in the cylinder using information from the initial situation at **A**.

**[2 marks]**

number of molecules = _____

**0 1 . 3** Calculate, in K, the change in temperature of the gas during the compression that occurs between **A** and **B**.

**[2 marks]**

change in temperature = _____ K

**0 1 . 4** Deduce whether the temperature of the gas changes during the compression from **B** to **C**.

**[2 marks]**

_____

_____

**Question 1 continues on the next page**

**0 1 . 5** Compare the work done on the gas during the change from **A** to **B** with that from **B** to **C** on **Figure 1**.

**[3 marks]**

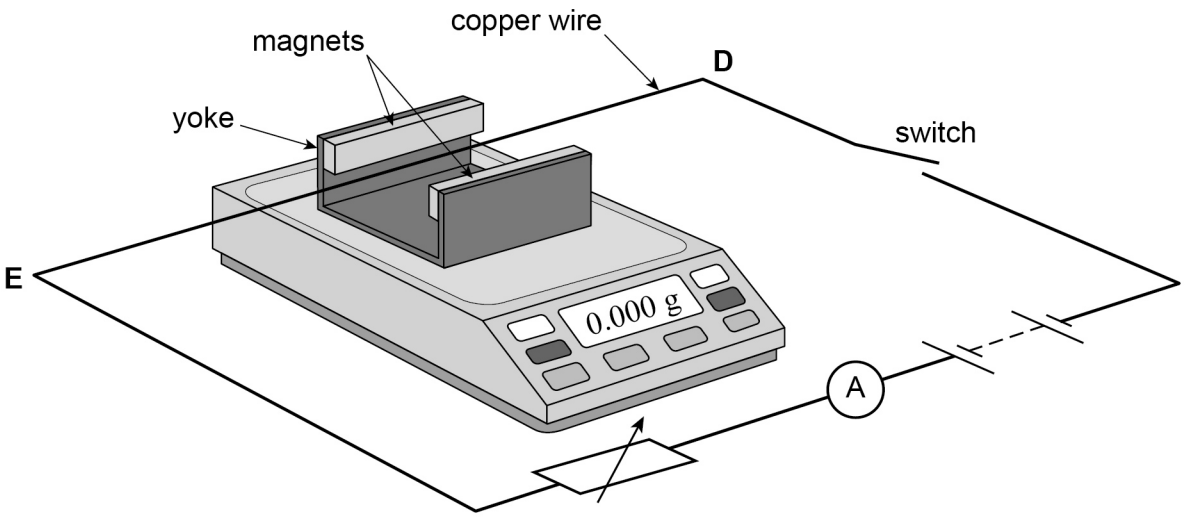
10

**Turn over for the next question**

**DO NOT WRITE ON THIS PAGE**
**ANSWER IN THE SPACES PROVIDED**

**0 2** **Figure 2** shows two magnets, supported on a yoke, placed on an electronic balance.

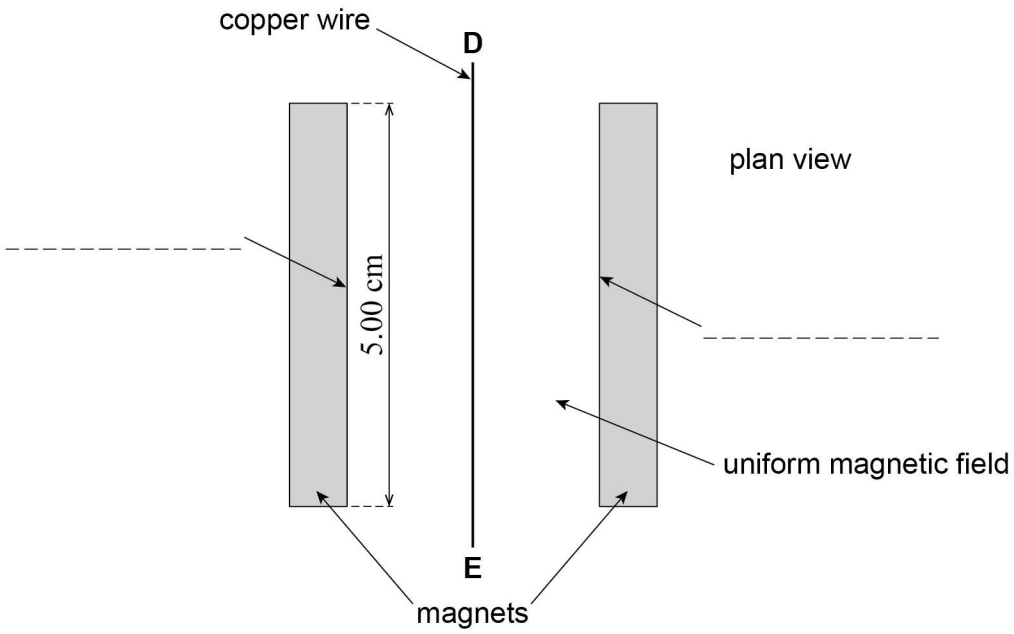
**Figure 2**




The magnets produce a uniform horizontal magnetic field in the region between them. A copper wire **DE** is connected in the circuit shown in **Figure 2** and is clamped horizontally at right angles to the magnetic field.

**Figure 3** shows a simplified plan view of the copper wire and magnets.

**Figure 3**




When the apparatus is assembled with the switch open, the reading on the electronic balance is set to $0.000$ g. This reading changes to a positive value when the switch is closed.

**0 2 . 1** Which of the following correctly describes the direction of the force acting on the wire **DE** due to the magnetic field when the switch is closed?

Tick (✓) the correct box.

**[1 mark]**

towards the left magnet in **Figure 3** ☐

towards the right magnet in **Figure 3** ☐

vertically up ☐

vertically down ☐

**0 2 . 2** Label the poles of the magnets by putting **N** or **S** on each of the two dashed lines in **Figure 3**.

**[1 mark]**

**0 2 . 3** Define the tesla.

**[1 mark]**

**0 2 . 4** The magnets are $5.00\ \text{cm}$ long. When the current in the wire is $3.43\ \text{A}$ the reading on the electronic balance is $0.620\ \text{g}$.

Assume the field is uniform and is zero beyond the length of the magnets.

Calculate the magnetic flux density between the magnets.

**[2 marks]**

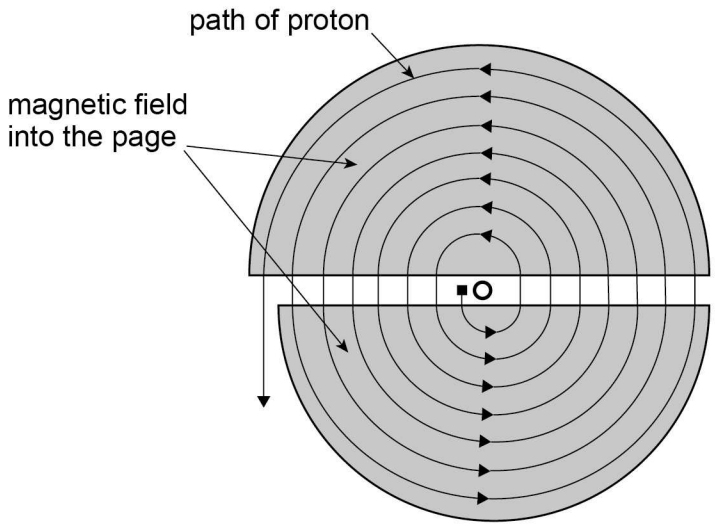
magnetic flux density = _____ T

**5**

**0 3** A cyclotron has two D-shaped regions where the magnetic flux density is constant. The D-shaped regions are separated by a small gap.
An alternating electric field between the D-shaped regions accelerates charged particles. The magnetic field causes the charged particles to follow a circular path.

**Figure 4** shows the path followed by a proton that starts from **O**.

**Figure 4**




**0 3 . 1** Explain why it is **not** possible for the magnetic field to alter the speed of a proton while it is in one of the D-shaped regions.

**[1 mark]**

**0 3 . 2** Derive an expression to show that the time taken by a proton to travel round one semi-circular path is independent of the radius of the path.

**[3 marks]**

**0 3 . 3** The maximum radius of the path followed by the proton is $0.55\ \text{m}$ and the magnetic flux density of the uniform field is $0.44\ \text{T}$.

Ignore any relativistic effects.

Calculate the maximum speed of a proton when it leaves the cyclotron.

**[2 marks]**

maximum speed = _____ $\text{m s}^{-1}$

**6**

**Turn over for the next question**

**0 4** The core of a thermal nuclear reactor contains a number of components that are exposed to moving neutrons.

**0 4 . 1** State what happens to a neutron that is incident on the moderator.

**[1 mark]**

**0 4 . 2** State what happens to a neutron that is incident on a control rod.

**[1 mark]**

**0 4 . 3** A slow-moving neutron is in collision with a nucleus of an atom of the fuel which causes fission.

Describe what happens in the process.

**[3 marks]**

**0 4 . 4** A thermal nuclear reactor produces radioactive waste.

State the source of this waste and discuss some of the problems faced in dealing with the waste at various stages of its treatment.

Your answer should include:

- the main source of the most dangerous waste
- a brief outline of how waste is treated
- problems faced in dealing with the waste, with suggestions for overcoming these problems.

**[6 marks]**

**Extra space is available on the next page if needed**

11

**0 5 . 1** Calculate the binding energy, in MeV, of a nucleus of $^{59}_{27}\mathrm{Co}$.

nuclear mass of $^{59}_{27}\mathrm{Co}$ = 58.93320 u

**[3 marks]**

binding energy = _____ MeV

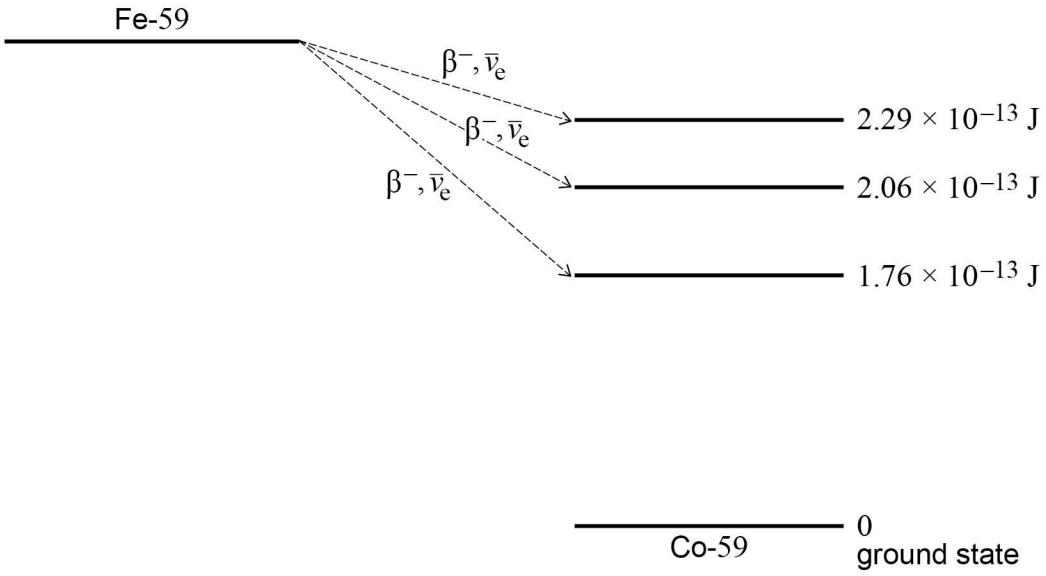
**Question 5 continues on the next page**

**0 5 . 2** A nucleus of iron Fe-59 decays into a stable nucleus of cobalt Co-59. It decays by $\beta^-$ emission followed by the emission of $\gamma$-radiation as the Co-59 nucleus de-excites into its ground state.

The total energy released when the Fe-59 nucleus decays is $2.52 \times 10^{-13}$ J.

The Fe-59 nucleus can decay to one of three excited states of the cobalt-59 nucleus as shown in **Figure 5**. The energies of the excited states are shown relative to the ground state.

**Figure 5**




Calculate the maximum possible kinetic energy, in MeV, of the $\beta^-$ particle emitted when the Fe-59 nucleus decays into an excited state that has energy above the ground state.

**[2 marks]**

maximum kinetic energy = _____ MeV

**0 5 . 3** Following the production of excited states of $^{59}_{27}\mathrm{Co}$, $\gamma$-radiation of discrete wavelengths is emitted.

State the maximum number of discrete wavelengths that could be emitted.

**[1 mark]**

maximum number = _____

**0 5 . 4** Calculate the longest wavelength of the emitted $\gamma$-radiation.

**[3 marks]**

longest wavelength = _____ m

**9**

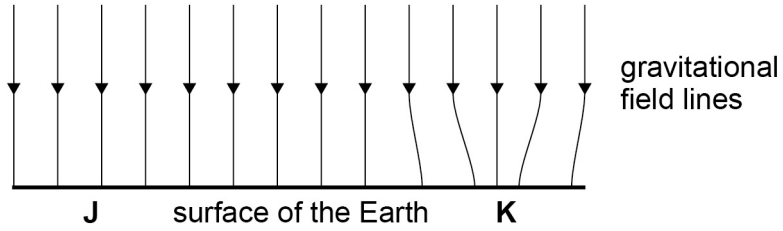
**Turn over for the next question**

**0 6 . 1** State what is represented by gravitational field lines.

**[1 mark]**

**0 6 . 2** **Figure 6** shows the gravitational field above a small horizontal region on the surface of the Earth.

**Figure 6**




Suggest why the field lines converge over a small area at **K**.

**[2 marks]**

**0 6 . 3** A ball travelling at constant speed passes position **J** moving towards position **K** in **Figure 6**.

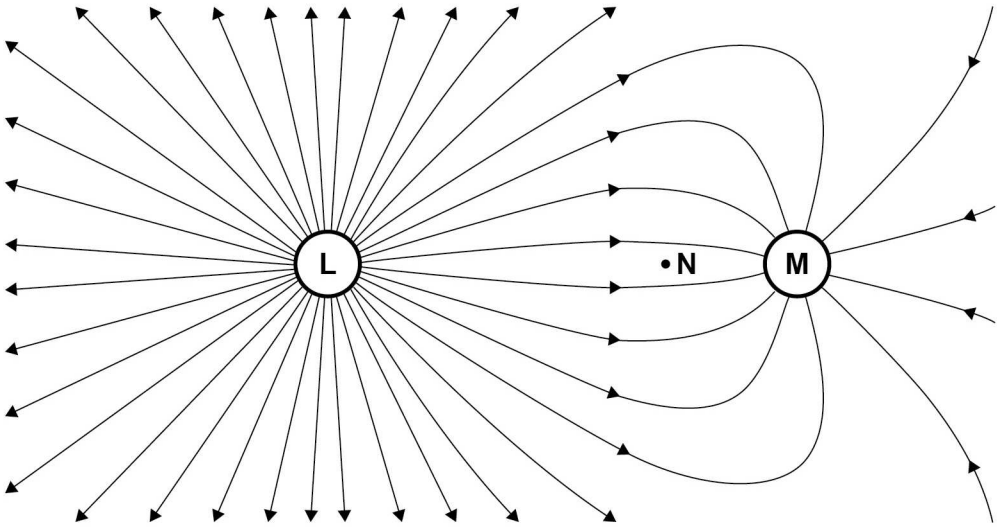
Assume friction is negligible.

Explain any change in the speed of the ball as it approaches **K**.

**[2 marks]**

**0 6 . 4** **Figure 7** shows lines of force for the electric field surrounding two charged objects **L** and **M**.

**Figure 7**




Explain why the lines of force shown in **Figure 7** cannot represent a gravitational field.

**[1 mark]**

**0 6 . 5** State which object **L** or **M** has a charge with the greater magnitude.

object _____

State which object **L** or **M** has a positive charge.

object _____

**[1 mark]**

**0 6 . 6** Draw, on **Figure 7**, an equipotential line that passes through point **N**.
Do **not** extend your line beyond the given field lines.

**[2 marks]**

**9**

**0 7 . 1** Derive an expression to show that for satellites in a circular orbit

$$T^2 \propto r^3$$

where $T$ is the period of orbit and $r$ is the radius of the orbit.

**[2 marks]**

**0 7 . 2** Pluto is a dwarf planet. The mean orbital radius of Pluto around the Sun is $5.91 \times 10^9$ km compared to a mean orbital radius of $1.50 \times 10^8$ km for the Earth.

Calculate in years the orbital period of Pluto.

**[2 marks]**

orbital period of Pluto = _____ yr

**0 7 . 3** A small mass released from rest just above the surface of Pluto has an acceleration of $0.617\ \text{m s}^{-2}$.

Assume Pluto has no atmosphere that could provide any resistance to motion.

Calculate the mass of Pluto.

Give your answer to an appropriate number of significant figures.

radius of Pluto = $1.19 \times 10^{6}\ \text{m}$

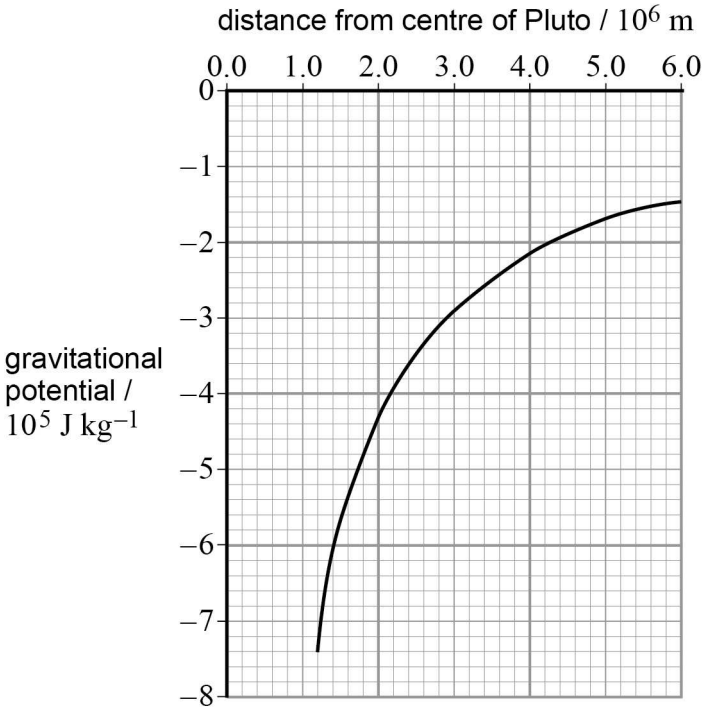
**[3 marks]**

mass of Pluto = _____ kg

**Question 7 continues on the next page**

**0 7 . 4** **Figure 8** shows the variation in gravitational potential with distance from the centre of Pluto for points at and above its surface.

**Figure 8**




A meteorite hits Pluto and ejects a lump of ice from the surface that travels vertically at an initial speed of $1400\ \text{m s}^{-1}$.

Determine whether this lump of ice can escape from Pluto.

**[3 marks]**

10

**END OF SECTION A**

## Section B

Each of Questions **8** to **32** is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD 

WRONG METHODS 

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked.

**0 8** A continuous stream of water falls through a vertical distance of $100\ \text{m}$.
Assume no thermal energy is transferred to the surroundings.
The specific heat capacity of water is $4200\ \text{J kg}^{-1}\ \text{K}^{-1}$.

What is the temperature difference of the water between the top and bottom of the waterfall?

**[1 mark]**

**A** $0.023\ \text{K}$ ⬭

**B** $0.23\ \text{K}$ ⬭

**C** $2.3\ \text{K}$ ⬭

**D** $4.3\ \text{K}$ ⬭

**0 9** A student measures the power of a microwave oven. He places $200\ \text{g}$ of water at $23\ °\text{C}$ into the microwave and heats it on full power for 1 minute. When he removes it, the temperature of the water is $79\ °\text{C}$.

The specific heat capacity of water is $4200\ \text{J kg}^{-1}\ \text{K}^{-1}$.

What is the average rate at which thermal energy is gained by the water?

**[1 mark]**

**A** $780\ \text{W}$ ⬭

**B** $840\ \text{W}$ ⬭

**C** $1.1\ \text{kW}$ ⬭

**D** $4.6\ \text{kW}$ ⬭

**1 0** The composition of a carbon dioxide ($CO_2$) molecule is one atom of ${}^{12}_{6}\text{C}$ and two atoms of ${}^{16}_{8}\text{O}$.

What is the number of molecules of $CO_2$ in $2.2\ \text{kg}$ of the gas?

**[1 mark]**

**A** $1.0 \times 10^{22}$ ⬭

**B** $3.0 \times 10^{22}$ ⬭

**C** $3.0 \times 10^{25}$ ⬭

**D** $4.7 \times 10^{25}$ ⬭

**1 1** What is the total internal energy of $2.4\ \text{mol}$ of an ideal gas which has a temperature of $15\ °\text{C}$?

**[1 mark]**

**A** $6.0 \times 10^{-21}\ \text{J}$ ⬭

**B** $1.4 \times 10^{-20}\ \text{J}$ ⬭

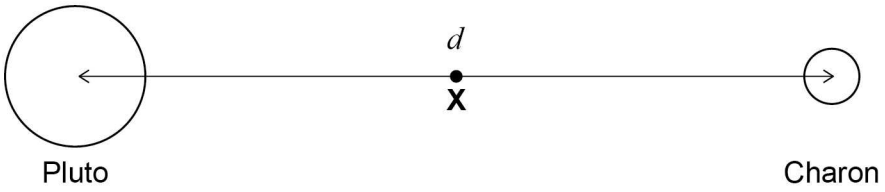
**C** $4.5 \times 10^{2}\ \text{J}$ ⬭

**D** $8.6 \times 10^{3}\ \text{J}$ ⬭

**1 2** Charon is a moon of Pluto that has a mass equal to $\frac{1}{9}$ that of Pluto.

The distance between the centre of Pluto and the centre of Charon is $d$.
**X** is the point at which the resultant gravitational field due to Pluto and Charon is zero.

not to scale




What is the distance of **X** from the centre of Pluto?

**[1 mark]**

**A** $\frac{2}{9}\,d$ ⬭

**B** $\frac{2}{3}\,d$ ⬭

**C** $\frac{3}{4}\,d$ ⬭

**D** $\frac{8}{9}\,d$ ⬭

**1 3** The distance between the Sun and Mars varies from $2.1 \times 10^{11}$ m to $2.5 \times 10^{11}$ m.
When Mars is closest to the Sun, the force of gravitational attraction between them is $F$.

What is the force of gravitational attraction between them when they are furthest apart?

**[1 mark]**

**A** $0.71F$ ⬭

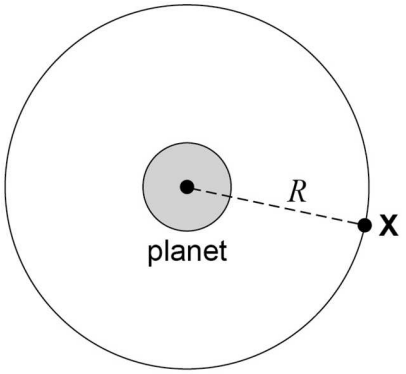
**B** $0.84F$ ⬭

**C** $1.2F$ ⬭

**D** $1.4F$ ⬭

**Turn over ►**

**1 4** A satellite **X** of mass $m$ is in a concentric circular orbit of radius $R$ about a planet of mass $M$.




What is the kinetic energy of **X**?

**[1 mark]**

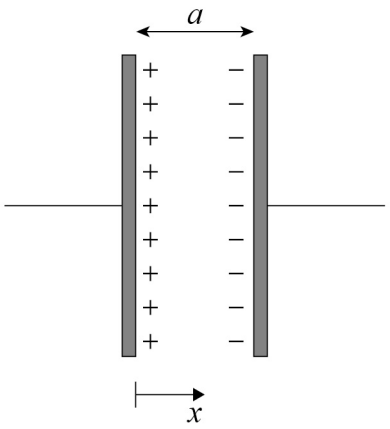
**A** $\frac{GMm}{2R}$ ⬭

**B** $\frac{GMm}{R}$ ⬭

**C** $\frac{2GMm}{R}$ ⬭

**D** $\frac{4GMm}{R}$ ⬭

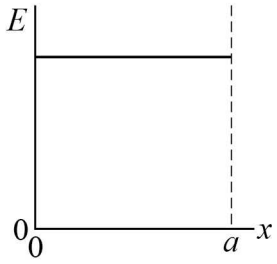
**1 5** Two parallel metal plates of separation $a$ carry equal and opposite charges.



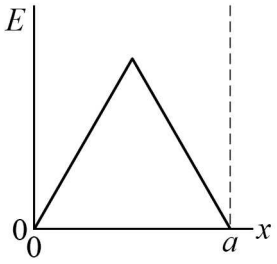

Which graph best represents how the electric field strength $E$ varies with the distance $x$ in the space between the two plates?

**[1 mark]**

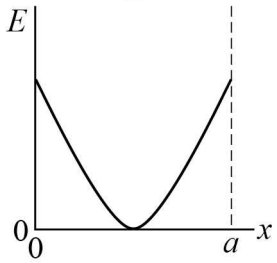
**A**



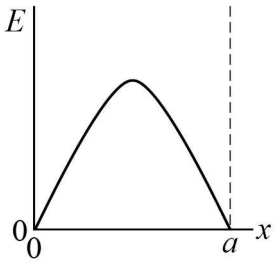

**B**




**C**




**D**




**A** ⬭

**B** ⬭

**C** ⬭

**D** ⬭

**1 6** A particle of mass $m$ and charge $q$ is accelerated through a potential difference $V$ over a distance $d$.

What is the average acceleration of the particle?

**[1 mark]**

**A** $\frac{qV}{md}$ ⬭

**B** $\frac{mV}{qd}$ ⬭

**C** $\frac{V}{mqd}$ ⬭

**D** $\frac{dV}{mq}$ ⬭

**1 7** An electron moves through a distance of $0.10\ \text{m}$ parallel to the field lines of a uniform electric field of strength $2.0\ \text{kN C}^{-1}$.

What is the work done on the electron?

**[1 mark]**

**A** zero ⬭

**B** $1.6 \times 10^{-17}\ \text{J}$ ⬭

**C** $3.2 \times 10^{-17}\ \text{J}$ ⬭

**D** $1.6 \times 10^{-21}\ \text{J}$ ⬭

**1 8** A parallel-plate capacitor is fully charged and then disconnected from the power supply. A dielectric is then inserted between the plates.

Which row correctly identifies the charge on the plates and the electric field strength between the plates?

**[1 mark]**

| | Charge | Electric field strength | |
|---|---|---|---|
| **A** | Stays the same | Increases | ⬭ |
| **B** | Increases | Decreases | ⬭ |
| **C** | Increases | Increases | ⬭ |
| **D** | Stays the same | Decreases | ⬭ |

**1 9** A capacitor of capacitance $C$ has a charge of $Q$ stored on the plates. The potential difference between the plates is doubled.

What is the change in the energy stored by the capacitor?

**[1 mark]**

**A** $\frac{Q^2}{2C}$ ⬭

**B** $\frac{Q^2}{C}$ ⬭

**C** $\frac{3Q^2}{2C}$ ⬭

**D** $\frac{2Q^2}{C}$ ⬭

**Turn over for the next question**

**2 0** A capacitor consists of two parallel square plates of side $l$ separated by distance $d$. The capacitance of the arrangement is $C$.

What is the capacitance of a capacitor with square plates of side $2l$ separated by a distance $\frac{d}{2}$?

**[1 mark]**

**A** $C$ ⬭

**B** $2C$ ⬭

**C** $4C$ ⬭

**D** $8C$ ⬭

**2 1** A capacitor of capacitance $120\ \mu\text{F}$ is charged and then discharged through a $20\ \text{k}\Omega$ resistor.

What fraction of the original charge remains on the capacitor $4.8\ \text{s}$ after the discharge begins?

**[1 mark]**

**A** $0.14$ ⬭

**B** $0.37$ ⬭

**C** $0.63$ ⬭

**D** $0.86$ ⬭

**2 2** A coil with $20$ circular turns each of diameter $60\ \text{mm}$ is placed in a uniform magnetic field of flux density $90\ \text{mT}$.

Initially the plane of the coil is perpendicular to the magnetic field lines as shown in **Figure X**.

**Figure X**

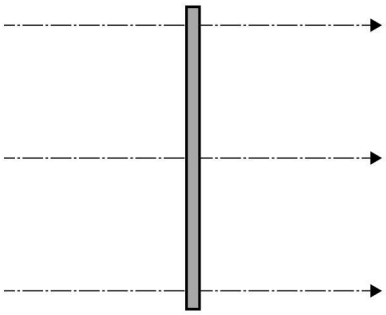
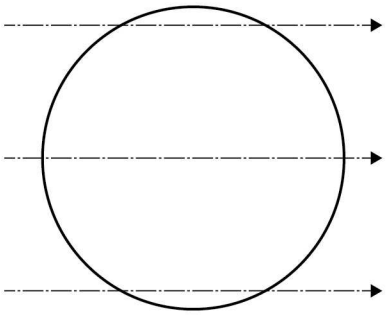


**Figure Y**



The coil is rotated about a vertical axis by $90°$ in a time of $0.20\ \text{s}$ so that its plane becomes parallel to the field lines as shown in **Figure Y**.
Assume that the rate of change of flux linkage remains constant.

What is the $\text{emf}$ induced in the coil?

**[1 mark]**

**A** zero ⬭

**B** $1.3\ \text{mV}$ ⬭

**C** $25\ \text{mV}$ ⬭

**D** $100\ \text{mV}$ ⬭

**2 3** The mean power dissipated in a resistor is $47.5\ \mu\text{W}$ when the root mean square ($\text{rms}$) voltage across the resistor is $150\ \text{mV}$.

What is the peak current in the resistor?

**[1 mark]**

**A** $2.3 \times 10^{-4}\ \text{A}$ ⬭

**B** $4.5 \times 10^{-4}\ \text{A}$ ⬭

**C** $2.3 \times 10^{3}\ \text{A}$ ⬭

**D** $4.5 \times 10^{3}\ \text{A}$ ⬭

**2 4** The National Grid is used to transfer electrical energy from power stations to consumers.

What conditions for the transmission voltage and the transmission current give the most efficient transfer of energy through the National Grid?

**[1 mark]**

| | Transmission voltage | Transmission current | |
|---|---|---|---|
| **A** | High | High | ⬭ |
| **B** | High | Low | ⬭ |
| **C** | Low | High | ⬭ |
| **D** | Low | Low | ⬭ |

**2 5** A mains transformer has a primary coil of $2500$ turns and a secondary coil of $130$ turns.
The primary coil is connected to a mains supply where $V_{rms}$ is $230\ \text{V}$.
The secondary coil is connected to a lamp of resistance $6.0\ \Omega$.
The transformer is $100\%$ efficient.

What is the peak power dissipated in the lamp?

**[1 mark]**

**A** $12\ \text{W}$ ⬭

**B** $24\ \text{W}$ ⬭

**C** $48\ \text{W}$ ⬭

**D** $96\ \text{W}$ ⬭

**2 6** The Rutherford scattering experiment led to

**[1 mark]**

**A** the discovery of the electron. ⬭

**B** the quark model of hadrons. ⬭

**C** the discovery of the nucleus. ⬭

**D** evidence for wave-particle duality. ⬭

**2 7** A Geiger counter is placed near a radioactive source and different materials are placed between the source and the Geiger counter.

The results of the tests are shown in the table.

| Material | Count rate of Geiger counter / $s^{-1}$ |
|---|---|
| None | 1000 |
| Paper | 1000 |
| Aluminium foil | 250 |
| Thick steel | 50 |

What is the radiation emitted by the source?

**[1 mark]**

**A** $\alpha$ only ⬭

**B** $\alpha$ and $\gamma$ ⬭

**C** $\alpha$ and $\beta$ ⬭

**D** $\beta$ and $\gamma$ ⬭

**2 8** Nobelium-259 has a half-life of 3500 s.

What is the decay constant of nobelium-259?

**[1 mark]**

**A** $8.7 \times 10^{-5}\ s^{-1}$ ⬭

**B** $2.0 \times 10^{-4}\ s^{-1}$ ⬭

**C** $1.7 \times 10^{-2}\ s^{-1}$ ⬭

**D** $1.2 \times 10^{-2}\ s^{-1}$ ⬭

**2 9** A pure sample of nuclide **X** containing $N$ nuclei has an activity $A$.
The half-life of **X** is $6000$ years.

A pure sample of nuclide **Y** containing $3N$ nuclei has an activity $6A$.

What is the half-life of nuclide **Y**?

**[1 mark]**

**A** 1000 years ⬭

**B** 3000 years ⬭

**C** 12 000 years ⬭

**D** 18 000 years ⬭

**3 0** Cobalt-60 has a half-life of $5.27$ years.

What is the total activity of $1.0$ g of cobalt-60?

**[1 mark]**

**A** $4.2 \times 10^{13}$ Bq ⬭

**B** $2.2 \times 10^{14}$ Bq ⬭

**C** $2.5 \times 10^{15}$ Bq ⬭

**D** $1.3 \times 10^{21}$ Bq ⬭

**3 1** The radius of a nucleus of the iron nuclide $^{56}_{27}\text{Fe}$ is $4.35 \times 10^{-15}$ m.

What is the radius of a nucleus of the uranium nuclide $^{238}_{92}\text{U}$?

**[1 mark]**

**A** $2.69 \times 10^{-15}$ m ⬭

**B** $2.89 \times 10^{-15}$ m ⬭

**C** $6.55 \times 10^{-15}$ m ⬭

**D** $7.05 \times 10^{-15}$ m ⬭

**3 2** Uranium-236 undergoes nuclear fission to produce barium-144, krypton-89 and three free neutrons.

What is the energy released in this process?

| Nuclide | Binding energy per nucleon / MeV |
|---|---|
| $^{236}_{92}\text{U}$ | 7.5 |
| $^{144}_{56}\text{Ba}$ | 8.3 |
| $^{89}_{36}\text{Kr}$ | 8.6 |

**[1 mark]**

**A** 84 MeV ⬭

**B** 106 MeV ⬭

**C** 191 MeV ⬭

**D** 3730 MeV ⬭

**END OF QUESTIONS**

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